# Project Report

ETS-5

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# Optical Efficiency Measurements of GEODSS Telescopes

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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# OPTICAL EFFICIENCY MEASUREMENTS OF GEODSS TELESCOPES

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# ABSTRACT

Optical Efficiency Measurements are reported for three telescopes used at the GEODSS Experimental Test System. The results of the measurements are needed to evaluate electro-optical sensor performance.

The optical efficiency is not a reflection on the manufacturer's skills but rather the number of optical pieces and coatings we have specified, and the dust collected during the operating period.

## I. Introduction

Telescope optical efficiency must be known to evaluate electro-optical sensor performance for the GEODSS program. The optical efficiency of a telescope will be defined as the following ratio:

$$T = \frac{\text{Total number of light quanta per second from the telescope comprising the image of a source}}{\text{Total number of light quanta per second entering telescope from the source}} \quad *$$

For these measurements, a Metrologic Model ML-680 He-Ne laser ($\lambda$ = 6328Å) was used as the light source, and a Tektronix Type J-16 Digital Photometer with #6502 probe was used to measure the total number of watts of laser light in and out of the telescope. The total wattage of the laser beam is directly proportional to the number of light quanta per second passing in the beam, and optical efficiency may be calculated by dividing the total number of watts in the laser beam out of the telescope by the total number of watts in the beam going into the telescope. The collection area of the optical detector used on the Tektronix J-16 photometer was larger than the area occupied by the laser beam and thus the power reading was for the entire beam. For the efficiency calculation, only a relative measure of power was necessary, and any anomalies present in the spectral response of the detector were irrelevant.

The GEODSS telescopes tested in this report are as follows:

1. 31-Inch Boller and Chivens Telescope, with configurations of:

   a. Cassegrain (Ritchey-Chretien) f/5 with Single Element Corrector Lens near Cassegrain Focus.

*The telescope thruput calculation must also include the observation of the secondary mirror and baffling (or the camera in the case of the prime focus).

b. Prime Focus f/2.75 with 5-Element Corrector Lens.

2. 14-Inch Boller and Chivens f/1.8 Folded Schmidt Telescope with 4-Element Corrector Lens.

3. 25-Inch Group 128 Telescope, with Configurations of:

a. Cassegrain f/10.

b. Prime Focus f/3.28 with 3-Element Corrector Lens.

The telescopes tested have various optical paths, and different lengths of time in service. The "old" optics refers to the 31" telescope installed in September 1975 and subject to much dust accumulation before dome completion and pressurization. The "new" optics is for 31" telescope #2 to be delivered late 1976.

By installing the "new" optics on telescope #1, it was possible to assess the losses due to the accumulation of dust and grime in field conditions. The laser technique will be recommended for use at future operational GEODSS sites to determine when the optics should be cleaned.

## II. The Measurements

Table 1 shows the measured optical efficiency of the new and old 31-inch telescope optics, the 14-inch and 25-inch telescopes, and other optical systems as indicated for comparison.

According to D. W. Herrod and L. Steimle of Boller and Chivens, 0.88 is a reasonable reflection efficiency at a wavelength of 6328Å for a new mirror coated with soft magnesium fluoride. If the secondary mirror in the 31-inch Cassegrain telescope has the same optical efficiency of 0.88, then the corrector lens in the telescope must have an efficiency of 0.94.

The old 31-inch primary mirror was noticeably dirty with loose dust and a hardened film on its surface. The effect of cleaning a small area on the mirror is evident in the efficiency measurements.

Another interesting observation for the 31-inch Cassegrain telescope is that if the old secondary and corrector lens have optical efficiencies of 0.88 and 0.94, respectively, i.e., the same as the new optics, the product of these numbers times the measured efficiency of the dirty primary (.73) is 0.60, which is close to the measured efficiency of the old 31-inch optics, which is 0.58. Apparently the dirty primary mirror was responsible for the decreased optical efficiency of the old 31-inch optics as compared to the new set. The secondary mirror, which faces down, did not appear near as dirty as the primary mirror.

All measurements in Table 1 are averages of several readings on each object, and single readings did not differ from the average by more than 1 or 2 per cent.

## III. Possible Sources of Error in the Measurements

1. <u>Linearity of Response of the Tektronix J-16 Digital Photometer</u>. The linearity of response with respect to light intensity of the J-16 photometer used for the measurements was tested by inserting 3 available Kodak gelatin neutral density filters in the light path between the laser and the photometer. The N.D. numbers were 0.2, 0.4, and 0.8. The results of the test are shown in Figure 1, which indicate that the device is suitably linear.

2. <u>The Effect of Different Optical Path Lengths in Air on the Photometric Readings</u>. Photometric readings of the laser beam were constant within 1% with the detector held a few inches from the laser to twenty feet away. One would not expect to see a change with 1% accuracy at these distances from consideration of atmospheric attenuation[1].

3. <u>The Effect of Different Laser Beam Diameters on Photometric Readings</u>. The laser beam diameter varied depending upon the distance of the detector from the laser, and the optical components in the light path. In all cases, the beam diameter was at most half the diameter of the detector window. A test was conducted in which a lens was inserted in the path between the laser and the detector to converge and diverge the beam to see if different beam diameters affected the photometric measurements. No effect was observed for beam diameters from pin-hole size to the diameter of the detector window.

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1 <u>RCA Electro-Optics Handbook</u>, pp. 82 ff, RCA Corporation (1974).

## IV. Conclusions

The measured optical efficiency of the old and 31-inch optical systems demonstrates the effect of a dirty primary mirror: the attenuation in visual magnitudes for the new optics is +0.34, while that for the old optics was +0.59. Another possible effect of a dirty primary mirror is an elevation of background brightness from the scattering of light from dirt on the mirror. For example, when a bright light was pointed at the dirty primary mirror, the entire mirror lit up almost like it had a paper covering. The new clean primary mirror exhibited no such effect. This could affect the detectability of satellites particularly on moonlit nights. A possible effect could be investigated by comparing recent sensitivity data taken with the old 31-inch optics and data to be taken with the new 31-inch optics.

To help keep the optics clean, I suggest the following:

1. The telescope should be sealed (i.e., capped with all vents closed) when not in use.

2. The telescope should be parked in a near horizontal position to minimize dust particles falling on the primary.

3. The air conditioner in the dome should be modified to cool with a little positive pressure to reduce inside dust.

4. Smoking in the dome should be prohibited.

Optical efficiency measurements should be made once a month to monitor dirt accumulation.

It is apparent the we may have to clean the primary mirror ourselves at regular intervals, and an investigation is under way to determine the best way to do it.

TABLE 1

MEASURED OPTICAL EFFICIENCY T OF INDICATED OPTICAL SYSTEMS

| Optical System Measured | Optical Efficiency (T) |
| --- | --- |
| 31" Telescope with new optics, Installed July 9, 1976; Cassegrain Configuration; f/5. | 0.73 |
| 31" Telescope, new optics, Prime Focus Configuration; f/2.75. | 0.75 |
| 31" New Primary alone. | 0.88 |
| 31" Telescope with original optics, Installed in August, 1975; Cassegrain Configuration; f/5. | 0.58 |
| 31" Old Primary alone, Dirty. | 0.73 |
| 31" Old Primary alone, Cleaned area. | 0.83 |
| 14" Folded Schmidt Telescope. | 0.56 |
| 25" Telescope, Installed in March, 1976, Cassegrain Configuration; f/10. | 0.76 |
| 25" Telescope, Prime Focus Configuration; f/1.8. | 0.74 |
| 25" Primary alone. | 0.87 |
| 8" Celestron Telescope; f/10. | 0.59 |
| 8" Celestron Primary + Twice through Schmidt Corrector Plate. | 0.62 |
| 25mm Celestron Eyepiece. | 0.90 |
| 40mm Celestron Eyepiece. | 0.94 |
| Celestron Right Angle Prism. | 0.94 |
| 135mm Schneider Comparon Lens; f/4.5. | 0.93 |

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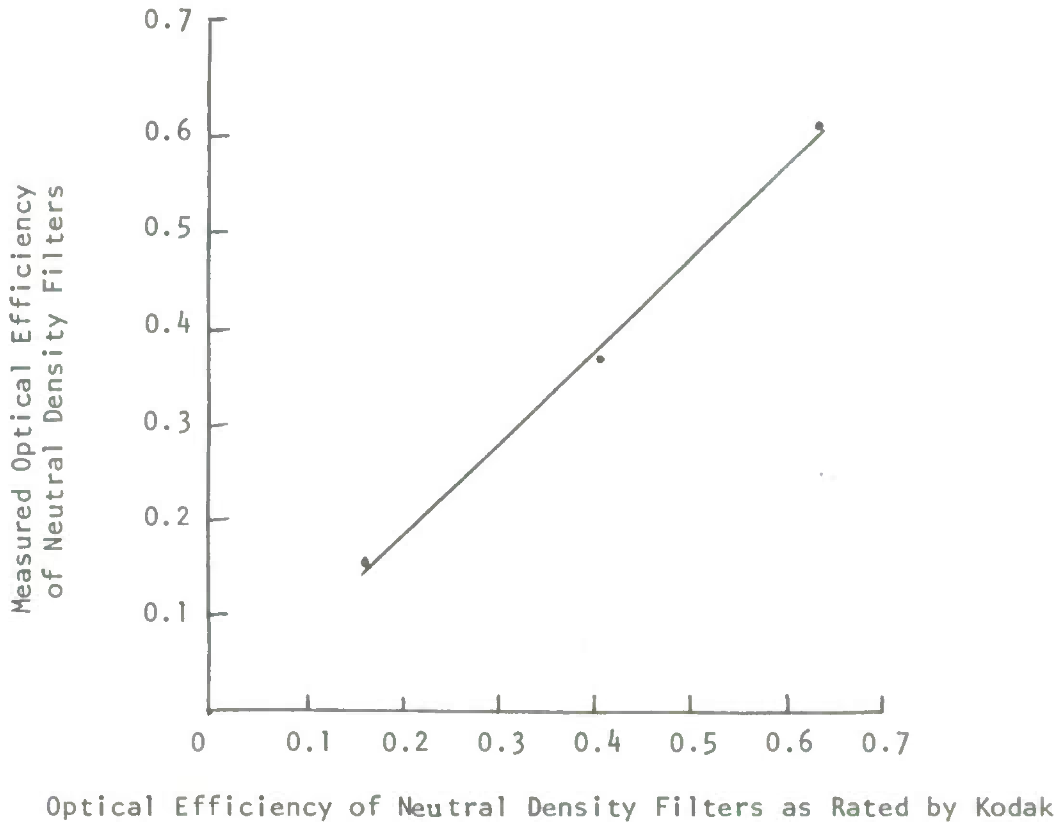


Fig. 1. Linearity Test of Tektronix J-16 Photometer and 6502 Probe.

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